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(54) **A process and apparatus for treatment of liquid and/or lumpy solid phases with gases in a static mixer**

(57) In the process the rate of flow of the gas phase is varied while in the periods of the flow variation the medium is contacted with at least one other medium consisting of liquid and/or lumpy solid phases which are induced to flow by virtue of the variations in the rate of flow of the gaseous medium and possibly the direction of flow of the gaseous medium.

The apparatus used comprises a static mixer whose casing (1) affords an internal flow passage having disposed along its length internal baffles (2) alternately at acute and obtuse angles (α, β) with the longitudinal axis or with a plane transverse to the longitudinal axis of the casing. Baffles of different types and in a variety of arrangements are disclosed.

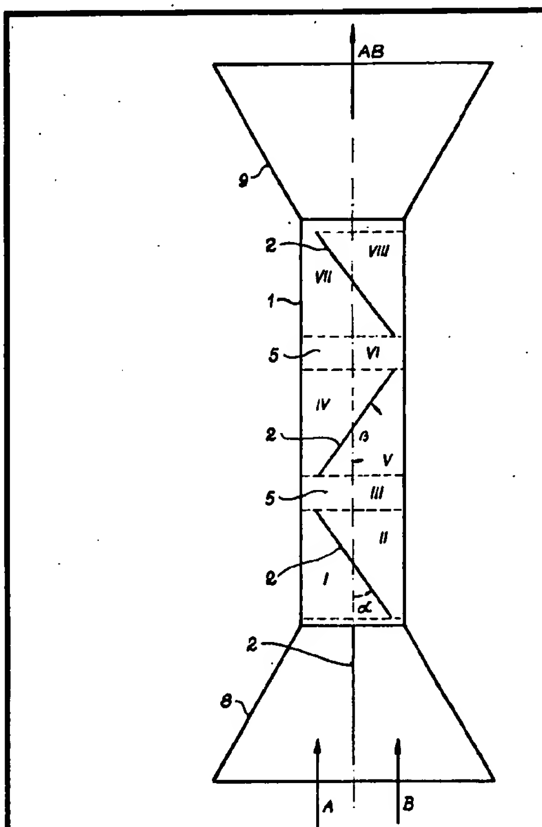

Fig. 1

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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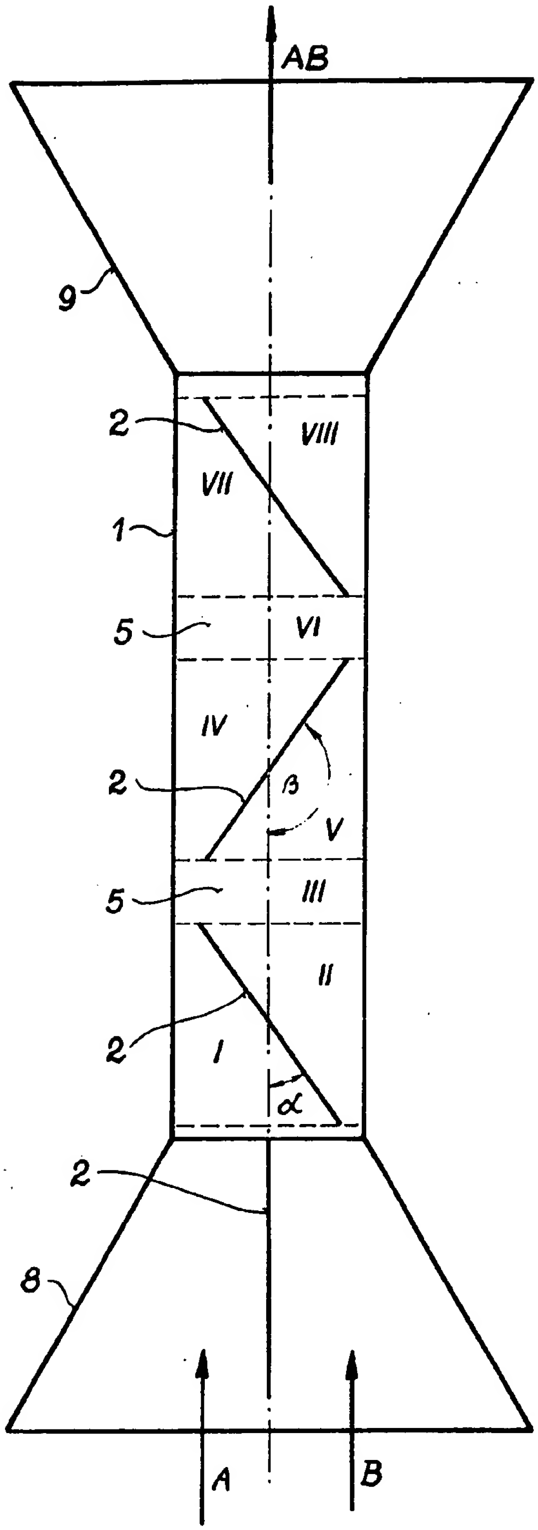

Fig. 1

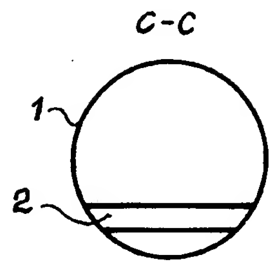

Fig. 1a

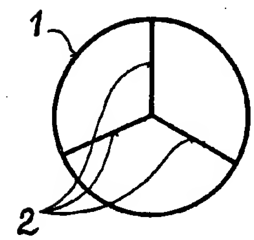

Fig. 1b

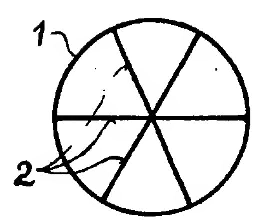

Fig. 1c

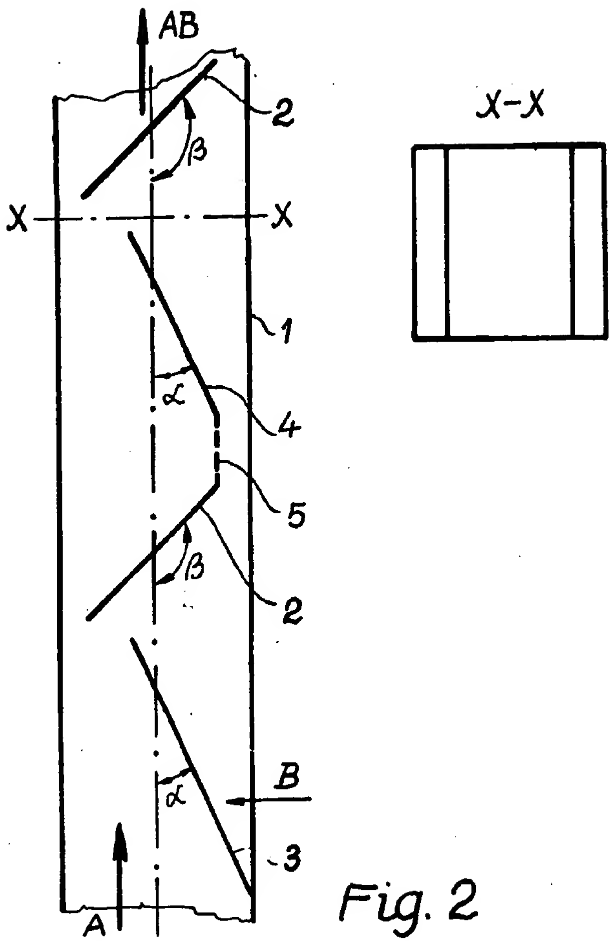

Fig. 2

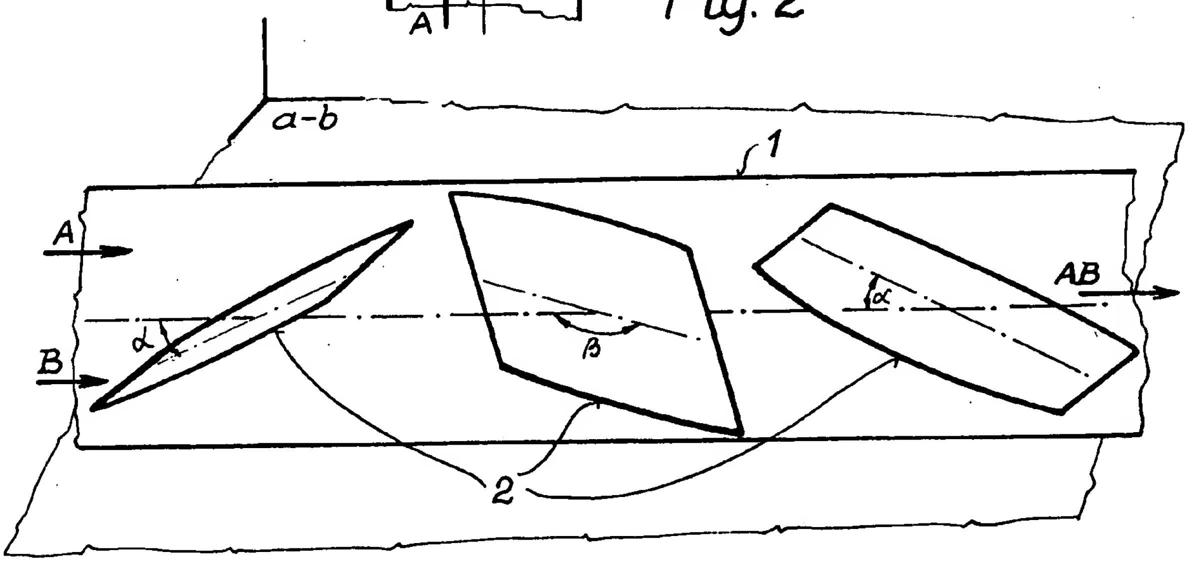

Fig. 3a

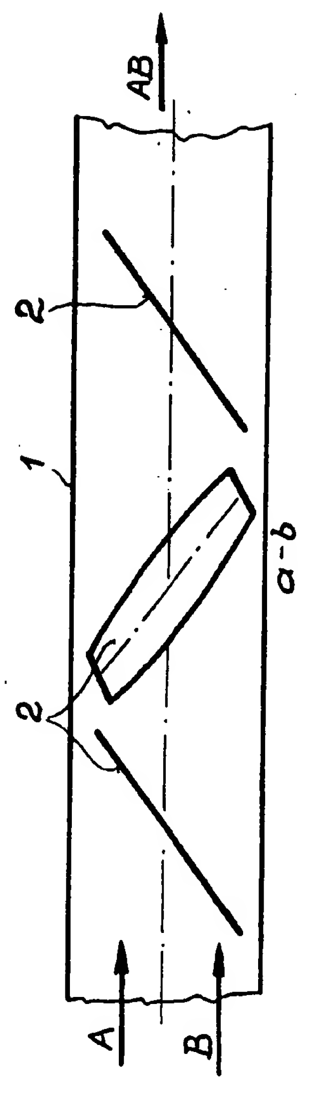

Fig.3b

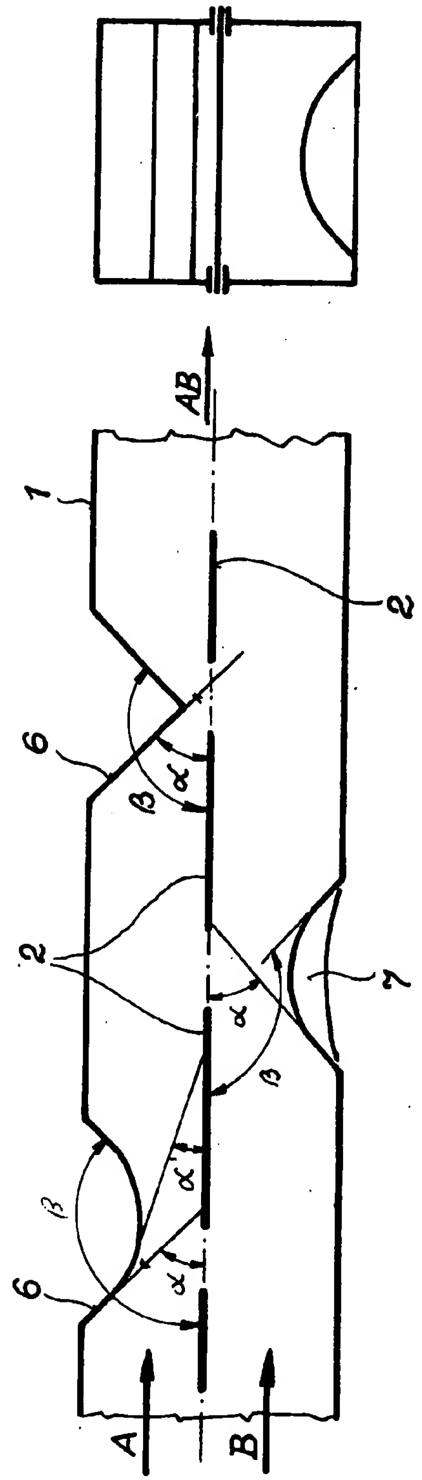

Fig.4

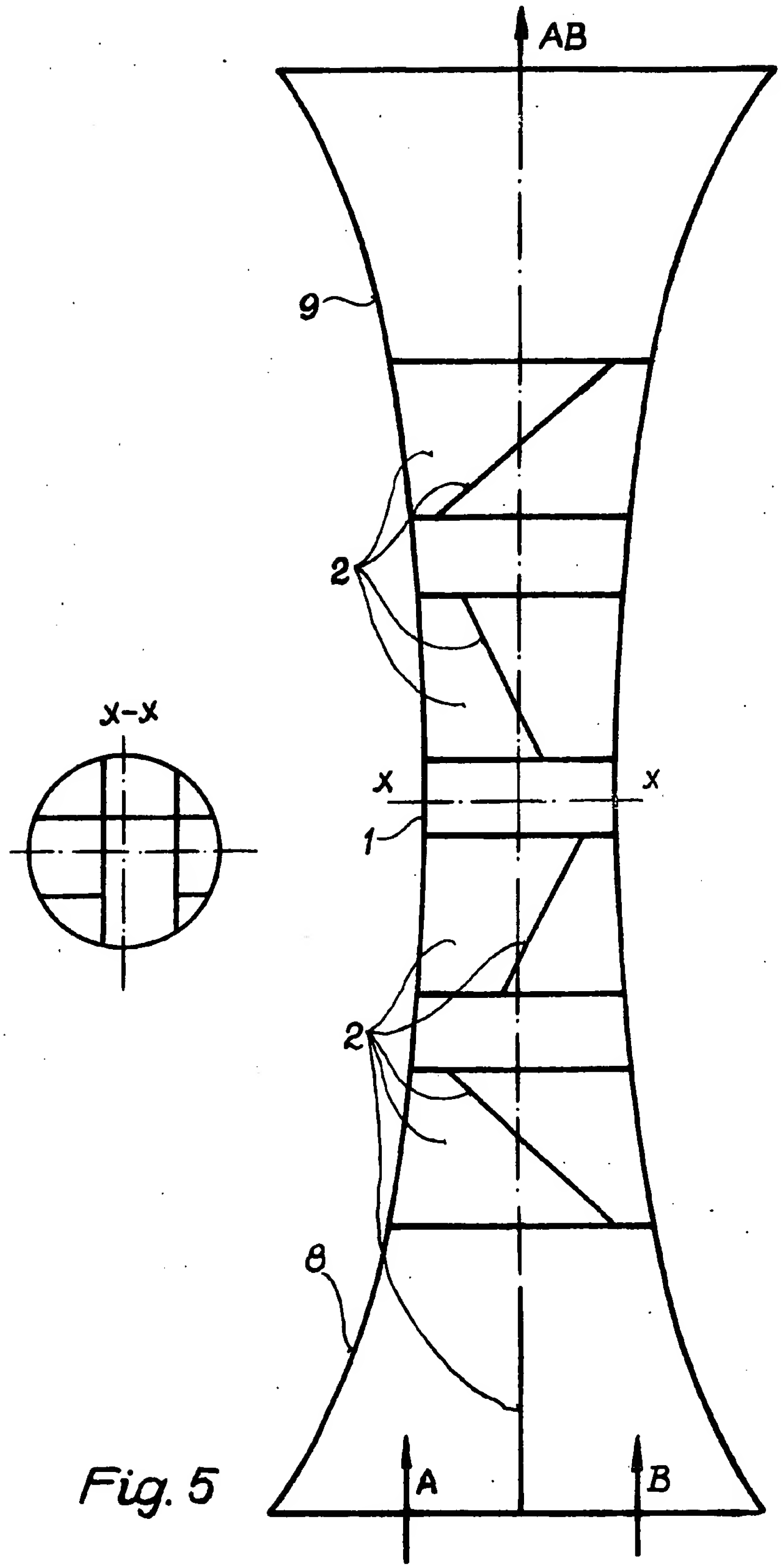

Fig. 5

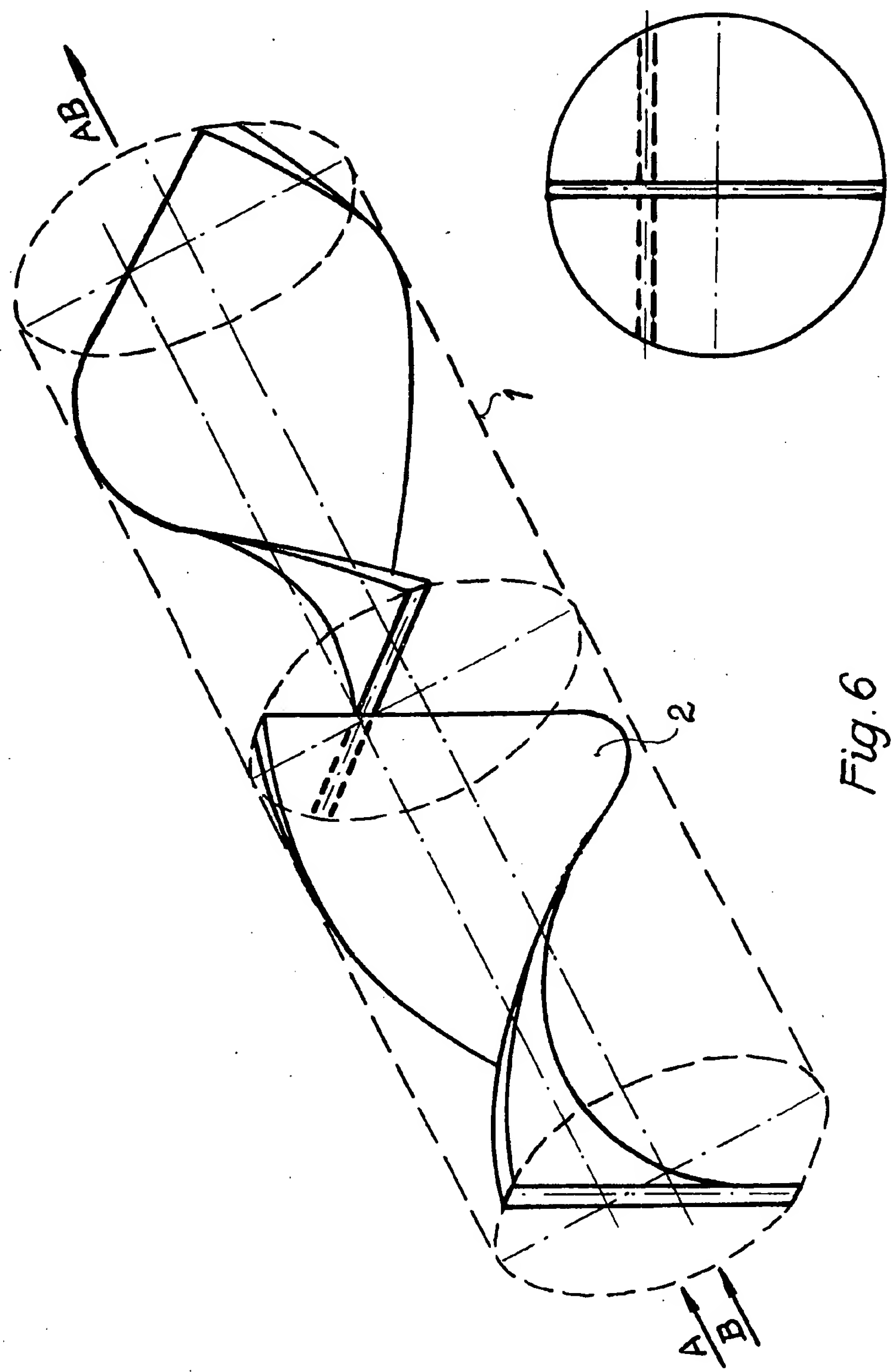

Fig.6

SPECIFICATION

Pr cess and apparatus f r tr atment f materials of liquid and/or lumpy solid phases with gases

The invention relates to a process and an apparatus for treatment of materials of liquid and/or of lumpy solid phases with materials of gas phases in a space /section/ bounded with wall/s/ and divided with at least one separation wall into parts.

As known, media of different phases can be stirred by means of static stirring elements and the phases can be contacted with each other intimately. "Intimate contact" means here that the phases are finely dispersed and, in this way, these are contacted with each other on very large surfaces, for as long as possible, and by creating as thin a surface boundary layer as possible. The stirring of the materials and the intimate contact between them offer the possibility of e.g. aerating, reacting, drying, etc.

The static stirring means that the stirring means is stationary and the media flow relative thereto. There are a number of known processes and apparatus for realizing static stirring.

In accordance with the United States patent No. 2.847.649 a helical element is placed in a cylindrical space providing stirring effect. According to the United States patent No. 2.847.196, a double pulley is used.

In United States patent No. 3.286.992 an apparatus is described in which the liquid flowing in a pipe is forced to a radial movement perpendicular to the pipe axis by means of successively opposite threaded helical separation walls dividing the pipe in axial direction into two parts. The edges of the contacting opposite threaded helical separation walls are positioned at an angle relative to each other and the set of separation walls divides the pipe always into two channels of equal cross sections.

According to the United States patents No. 3.871.624 and 3.918.688 both media of different phases flow through channels of equal cross sections created by parallel separation walls of equal lengths and the channels are positioned longitudinally in the pipe, perpendicularly and offset relative to each other. This channel system divides the media continuously into parts and stirrs them hereby.

In each process described above the separated space, e.g. pipe in which the media flow ar divided into parts of equal cross sections in the length by means of separation wall/s/ /positioned parallelly to the pipe axis/, and th stirring effect is induced with a forced flow perpendicular to the axis or with continuous further division of th media.

Said apparatus and stirring proc sses have disadvantages, as follows: The effective energy used for stirring is relatively small, consequently the length of the pipe and th ratio L/D, i.e. length/diameter will be great, the mixing will be similar rather to a "corkscrew"-like flow than to a laminar flow occurring in an empty pipe, however, it is still rather different from the former one. The resulting shearing action is small, therefore many serially positioned units must be used to achieve the necessary stirring effect. When greater geometric dimensions are wanted, the manufacturing process have to be modified to a large extent for producing an insert giving a good static stirring. In a given apparatus the relative input flow-rate of the phases can be varied in a relatively small range. Furthermore, expecially the apparatus described in United States patent No. 3.871.624 is prone to contamination.

There are known injectors which are provided with a confusor at the input point of the media and with a diffusor and at the output thereof. It is known furthermore that a medium of given mass moved alternately in opposite directions can be brought in resonance.

The object of the present invention is to provide a process and an apparatus realizing the said process, by means of which a stronger stirring effect and together with this a more intimate phase contacting, hence a more intensive treatment can be realized, the production of the apparatus is simpler and finally the costs are smaller.

According to the present invention, the process and the apparatus are based on the recognition that stirring effect can be made stronger and phase contacting surfaces can be significantly increased by varying the rate flow of the media flowing in parallel but separately by separation wall/s/—on the one hand, the media of liquid and/or of lumpy solid phases, on the other hand the gas phase—alternately in opposite senses, by varying the angles of the separation walls relative to the pipe axis alternatively at acute and obtuse angles, while the medium /media/ of higher rate of flow is /are/ contacted with the medium /media/ of smaller rate of flow at or through the discontinuity points of the separation wall/s/. In this simple arrangement the sucking effect of the medium /media/ flowing with higher rate results in a surprisingly significantly increased stirring effect. Namely, a great local turnbulency develops, even if the flowing of the medium /media/ is laminar. A further recognition of the present invention is that the sucking effect of media flowing with high rate is so significant that surprisingly an increased stirring effect is observed, ven if the separation wall/s/ p sitioned at an inclined angle relative to the pipe axis is /are/ made simply of flat plates.

Another rec gnition is that, surprisingly, by varying /sl wing or accel rating/ the rate of

flow of a single medium alternately in opposit senses, a second medium can be induced to flow or the rat of flow thereof can be varied. On the other hand it m ans that the rates of flow of different m dia can be vari d even in a given apparatus in a great range.

According to our recognition, it is sufficient to cause two media to flow in the space surrounded by boundary wall/s/, e.g. in a pipe, provided with a single separation wall consisting of a set of appropriately positioned plates, in a way such that the rate of flow of the medium relative to the second medium increases or decreases alternately, and said medium is contacted with said second medium at or through the discontinuity points of the set of successively placed plates.

In accordance furthermore with our recognition, said advantageous effect can be achieved also when the boundary wall/s/ is /are/ not the one/s/ which is /are/ straight, and the separation walls are not positioned alternately at acute and obtuse angles relative to the longitudinal axis, but on the contrary, the separation walls are positioned in a straight line and the boundary wall/s/ is /are/ articulated with various openings or neckings.

A further recognition is that the above-mentioned advantageous effects can be achieved with smaller energy requirements, if the medium /media/ is /are/ accelerated stepwise at the input into the static stirring space, and slown down stepwise at the output.

A further recognition is that the speed variation alternately in opposite senses from the point of view of the resonance of a given mass is of equivalent effect, as the movement of alternately opposite directions. Therefore the system comprising the phases and gases to be treated can also be brought in or near to resonance, and in this range the flow requires less energy.

The process according to the present invention consists essentially of the following steps: in a space surrounded with boundary wall/s/ and separated with at least one separation wall, the rate of flow of the medium of gas phase is varied alternately in opposite senses, while at least two media flowing in space sections divided with separation wall/s/ are contacted during the phases of the speed variation, and the media consisting of materials of liquid and/or lumpy solid phases are induced to flow by flowing the medium of gas phase and/or the rate/s/ and/or the directions/s/ is /are/ varied, in a given case the media are brought in or near their resonance point by varying the speed alternately in opposite directions, and in a given case the medium /media/ is /are/ stepwise acceler-at d at the input into the spac surrounded with boundary wall/s/ and divid d with at least one separation wall and/or stepwise slown down at the output.

In a pr ferred embodiment of the process according to the present invention, in one or mor m dia at least during a part of the alt rnat ly opposite sensed speed variation a flow deviated from the main flow direction along the axis, in the extreme case approximately perpendicular thereto, is induced.

In a preferred embodiment of the process according to the present invention the flow deviated from the main flow direction along the axis, in extremity approximately perpendicular thereto, is induced at the end of and/or after the alternately opposite sensed speed variation.

Besides the main flow direction, the deviated and in the limit approximately perpendicular radial flow component can be induced so that the bed of the separation wall according to the present invention induces a radially forced flow. In this way in a preferred embodiment of the process according to the present invention, the media are forced into a from the main flow direction deviated and in extremity perpendicular flow by means of the bend of the separation wall dividing the space into sections.

The increased stirring effect achieved by the process according to the present invention can be further increased, when simultneously with the contracting of the media by interrupting the continuity of the separation wall, the given medium is also divided into parts by means of the edge of said separation wall opposite to the flow. With this measurement a given medium can be divided into parts at a given point going on in the flow direction. The media flowing in parallel can be divided into parts at the same given point, although in the various parallel flowing media the division into parts can be effected at different points shifted in the flow direction. Also, in a preferred embodiment of the process according to the present invention the media separated by means of separation wall/s/ and flowing in parallel are divided into parts simultaneously or shifted in the flow direction at the discontinuity of the separation wall/s/ by means of the edges opposite to the flow direction of the separation wall/s/.

In another preferred embodiment of the process according to the present invention the parallel flowing media are divided into parts after the discontinuity of the separation wall/s/ by means of turning the edge/s/ of the continuation of the separation wall/s/ being opposite to the flow in a given angle relative to the preceding separation wall end.

The apparatus according to the present invention comprises walls around th longitudinal axis comprises separation wall/s/, which include at least partly alternat ly acute or obtus angles with the longitudinal axis and/or with the b undary wall/s/ around the l ngitudinal axis, further it comprises

piece/s/ of separation wall/s/, separation wall/s/ and/or boundary wall/s/ contracting stepwis at the input p int, boundary wall/s/ expanding stepwise at the output point of the media, and furthermore comprises spaces surrounded by the boundary and the separation walls and in certain cases by the separation wall/s/ comprising at least in a part of the longitudinal axis alternately contracting or expanding sections.

The apparatus according to the present invention is not affected in essentials by the fact that not all of the separation walls include alternately acute or obtuse angles with the longitudinal axis and/or with some predetermined plane /a–b/ laid across the longitudinal axis or with the boundary walls around the longitudinal axis, it is sufficient if at least a part of the separation walls include an acute or obtuse angle therewith.

The plane /a–b/ laid across the longitudinal axis should be predetermined, and at least a part of the separation walls should be positioned alternatively at acute or obtuse angles relative thereto. With the separation walls positioned in the said way, a second plane can in general be laid across the longitudinal axis, with which the half of the separation walls including acute or obtuse angles with said plane /a–b/ include a right angle, the other half of the separation walls include either always acute angles or always obtuse angles with said second plane. In a preferred embodiment of the apparatus according to the present invention the separation walls include always equal acute angles or always equal obtuse angles with the longitudinal axis, with the plane /a–b/ or with the boundary wall/s/. In another embodiment of the apparatus according to the present invention the actue or obtuse angles may be of different magnitudes. These may be different in such a way that the successive acute angles or the successive obtuse angles along the longitudinal axis are of different values, but the expression "different values of angles" mean as well that the angles between the separation wall/s/ and/or the boundary wall/s/ forming a single contracting or expanding space vary continuously. An embodiment of the apparatus according to the present invention comprises also separation wall/s/ including alternately acute or obtuse angles with the longitudinal axis and/or with a predetermined plane /a–b/ laid across the longitudinal axis or with the boundary wall/s/ around the longitudinal axis, furthermore, said apparatus comprises separation wall pi ce/s/.

In a pr ferred embodiment of the apparatus according to the present invention the separation wall/s/ has /have/ discontinuities.

A preferr d embodiment of the apparatus according to the present invention comprises separation wall/s/ of helical form including alternately acute or obtuse angles with the longitudinal axis, including continuously varying angles with some predetermined plane /a–b/ laid across the longitudinal axis.

Another preferred embodiment of the apparatus according to the present invention comprises opposite threaded successive helical separation walls.

Another preferred embodiment of the apparatus according to the present invention comprises a few or all of the successive separation walls turned by a given angle on the tail relative to the preceding end.

Referring to Fig. 1 to 6, the embodiments of the apparatus according to the present invention are shown in schematic sectional views.

Referring to Fig. 1, a boundary wall 1 of circular section around the vertical longitudinal axis and separation walls 2 are shown, said separation walls 2 include with the longitudinal axis an acute angle α and an obtuse angle β alternating with the direction of arrow AB. In the embodiment of the example α and β are complementary angles. The space section I contracts along the longitudinal axis /that is, in the direction of arrow AB/, while simultaneously the space section II expands and the space section III surrounded by boundary wall 1 of circular section is of equal cross section, the space section IV expands in the direction of the longitudinal axis and at the same time the space section V contracts. In this way the space section I and the space sections IV and VII following said space section I and the space sections II, V and VIII etc. respectively contract and expand alternately, and said space sections I, IV and VII contract and expand alternately in a similar way. In a preferred embodiment of the apparatus according to the present invention, said space sections I, IV, VII, etc. contract and expand alternately, while said space sections II, V, VIII, etc. are of equal cross sections. The separation walls 2 in Fig. 1 can be regarded as a single separation wall having a discontinuity at places 5. In Fig. 1 arrow A represents the input point of the first medium, and arrow B represents the input point of the second medium. Arrow AB represents the mixed medium outputting (exiting) from the apparatus. The boundary walls 8 form a confusor, hereby said boundary walls set up a contracting space at the input point of the media A and B, and said contracting space speeds said media stepwise up. The boundary walls 9 form a diffusor, thereby at the output point of the mixed medium AB an expanding space is set up which slows the medium AB stepwise down.

R ferring to Fig. 1.a, a section tak n up in Fig. 1 through C–C is shown, where insid the b undary wall 1 of circular secti n a single separation wall 2 is placed and said separation wall 2 divides the space into two parts. In Fig. 1.b three in angle assembling

separation walls 2 are shown which divide the space inside the boundary wall 1 into three space sections. Referring to Fig. 1.c, six separation walls 2 assemble in the axis and thereby the spac inside the boundary wall 1 is divided into six sections.

Referring to Fig. 2 and 2a, the longitudinal axis of the apparatus is horizontal, said boundary wall 1 is of rectangular section, the separation walls 2, 3 and 4 are of different lengths. Said separation wall 3 extends up to said boundary wall 1, thereby providing a side inlet for said phase B. Said separation walls 2 and 4 form a single continuous separation wall provided with discontinuities at place 5. In Fig. 2 said discontinuity 5 is a hole or a screen or filter, and the angles α and β are not complementary angles.

Referring to Figs. 3.a and 3.b, said separation walls 2 including alternately acute or obtuse angles with some plane /a–b/ laid across the longitudinal axis are shown. In Fig. 3.a the predetermined plane /a–b/ is perpendicular to the plane of the figure. Said separation with said plane /a–b/ , and at the same time include acute or obtuse angles with the longitudinal axis as well. In Fig. 3.b an extreme case is shown for the arrangement of Fig. 3.a, wherein an example is shown for the apparatus according to the present invention, where said predetermined plane /a–b/ may include an arbitrary angle with the plane of the figure, and said separation walls 2 include alternately acute or obtuse angles with said plane /a–b/. When said plane /a–b/ is turned in the plane of the figure, half of the separation walls include a right angle, that is, these are perpendicular to this turned plane /a–b/.

Referring to Figs. 4 and 4a the separation walls 2 do not include angles, these separation walls 2 are placed in a plane. Said separation walls 2 can also be regarded as a single separation wall 2 provided with discontinuities. On said boundary wall 1, which is in the example of rectangular cross section, narrowings formed by notches 6 of arcute or angled form and by a notch 7 of circular form are provided. In the direction of the flowing, said narrowings form together with said separation wall 2 a contracting, then expanding space.

Referring to Figs. 5 and 5a, an apparatus is shown similar to Fig. 1. The boundary wall 1 together with the confusor boundary wall 8 and diffusor boundary wall 9 form a single arch resulting in a changed resonance point concerning the given mass of material.

Referring t Figs. 6 and 6a the separation walls are positi ned in a helical form threaded around an axis including an angle with the longitudinal axis. In this way said separation walls include continuously varying angles with som pr determined plane /a–b/ laid across the longitudinal axis. The succ ssive s paration walls 2 are thr aded opposit ly, and each separation wall tail is positioned at a certain angle relative to the preceding separation wall end.

The elements of the apparatus according to the present invention do not move in action. In general at least two media are caused to flow through the apparatus, however, these two media may be of the same material in which case there is a difference in a physical characteristic /e.g. in temperature/. In the figures in general two media are designated with A and B. The media A and B flow into separate space sections of the apparatus in the directions shown by the arrows, and on the other end of the apparatus a fully mixed medium AB comes out.

The process and apparatus according to the present invention are explained in the following with non-limiting examples.

Example 1

Gas, e.g. air is to be dispersed in form of fine bubbles in liquied /e.g. water, methanol, acetone, etc./. From the air fed in below in the traditional way, e.g. by means of a nozzle, primary bubbles of diameter 10 to 50 μm arise, which in an altitude of H~0.3 to 0.5 m agglomerate to bubbles of size of cm order.

The bubbles of size of cm order are fed in the apparatus according to the present invention, and by using a pipe diameter of ϕ 50 mm and 10 to 50 pieces of alternately opposite threaded separation wall elements, after the elements bubbles of diameter 10 to 50 μm come out. The homogeneity of the dispersion measured directly after the last element is $\sigma/\sigma_o = 10^{-2}$.

Example 2

In a sewer catch basin a concentration of >2 mg/l O_2 is to be reached. By contacting the water in the basin with air by means of a mechanical surface paddle stirring apparatus, the oxygen content of the air diffuses in the solution with an efficiency of $\eta = 0.7$ to 0.75. In the apparatus according to the present invention, using a pipe of diameter $\phi = 100$ mm and of length L = 1000 mm, provided the pipe with separation wall elements of length 100 mm, the efficiency will be $\eta = 0.85$ to 0.90.

For example in case of feeding air in water of temperature 20°C with a rate of 0.6 to 0.8 m^3/min, the energy consumption will be

— by using a mechanical surface stirring apparatus, 1.7 to 3.5 HP/100 m^3

— by using the process according to the pres nt invention 1.1 to 1.8 HP/100 m^3/in this latter case a compression efficiency of 70% is assumed/.

Example 3

In biological reactors in order to get a liquid rate of flow of min. 15 cm/sec, by using a

surface stirring apparatus a water depth of approximately 1 m can be stirred.

By using the apparatus according to the present invention, th whole mass can be circulated with a volume flow by units of 1 to 3 m^3/h, and the efficiency of the circulation increases with the height of the liquid. By means of the given volume flow solid material of 10 to 15 g/l can be floated (suspended).

Example 4

Polyvinyl chloride /PVC/ powder made by a suspension process is coloured with a master-mixture. The rate of mixing is: 100 kg PVC powder to 0.5 kg master mixture.

By performing the mixing in a traditional intermittent-duty strip stirring apparatus having a charge capacity of 1.2 m^3, a residence of 30 to 45 minutes and an effective shaft output of $P = 4$ to 5 kW/m^3 are necessary.

In an apparatus according to the invention comprising a pipe of length 2 m and of diameter ϕ 100 mm, by using air of pressure $p = 2$ att and of an air flow rate of 50 to 60 m^3/h, a capacity of 30 m^3 charge/h can be achieved. The necessary residence time is namely between 1/6 and 1/10 of the residence time necessary for the mixing in a traditional stirring apparatus. In case of a charge capacity of 1.2 m^3, the performance of the traditional apparatus is 1.6 to 2.4 m^3/h, that is, the capacity of the apparatus according to the present invention is nearly 10 to 20 times higher.

The manner of applying the process and apparatus according to the present invention is made clear by the examples. There are many and various possibilities and areas for using the described process and apparatus; it is not restricted, naturally, to the cases described in the examples and in the figures.

Our process and apparatus is—even on the basis of the present data—more advantageous and cheaper than the hitherto known static stirring processes and apparatus. By using these, an increased stirring effect, and in connection with this bigger contacting surfaces, an increased heat-transfer and an increased shearing effect can be achieved. Consequently, in order to achieve the same result it is sufficient to use a shorter pipe.

In the apparatus no contamination appears on the boundary and separation walls or the measure thereof is much smaller.

CLAIMS

1. A process for stirring of materials of liquid and/or lumpy solid phases with gases in a space (s ction) bounded with wall(s) and divided into sections with at least one s paration wall, wherein the rate of flow of at least the media of gas phase is varied alternately in opposite senses, while in the given periods of the spe d variation, at least two media separated by separation wall(s) are contacted with each other and the medium (media) consisting of liquid and/or lumpy solid phases are induced to flow by causing the medium of gas phas to flow, and the rat and/or direction of the flow of the media are varied, in given cases the media are brought to or near their resonance point by the alternately opposite speed variations and in given cases at the inlet to the said space (section) the medium (media) is (are) stepwise accelerated and/or at the outlet from said space is (are) stepwise slowed down.

2. A process for the static stirring of media as claimed in Claim 1, wherein at least during a part of the altarnately opposite speed variation, a flow deviating from the main flow direction along the axis in the limit approximately perpendicular thereto, is also induced in at least one medium.

3. A process for the static stirring of media as claimed in Claim 2, wherein a flow deviating from the main flow direction along the axis, in the limit approximately perpendicularly thereto, is induced at the end of and/or after the alternately opposite speed variation.

4. A process for the static stirring of media as claimed in Claims 2 or 3, wherein the media are forced to flow in deviation from the main flow direction, in the limit approximately perpendicularly thereto, by curving said separation wall dividing the space into sections.

5. A process for the static stirring of media as claimed in any of claims 1 to 4, wherein the media are contacted in the periods of the speed variation by interrupting the continuity of the separation wall(s) dividing the space into sections.

6. A process for static stirring of media as claimed in any of claims 1 to 5, wherein the media flowing in parallel and separated by separation wall(s) are divided into parts at the discontinuities of the separation wall(s) by means of the edge(s) of the separation wall(s) opposite to the flow, simultaneously or shifted in the direction of the flow.

7. A process for static stirring of media as claimed in any of Claims 1 to 6 wherein the parallelly flowing media are divided into parts after the discontinuities of said separation wall/s/ by turning the edges of the continuation of said separation wall/s/ opposite to the flow by a given angle relative to the preceding separation wall end/s/.

8. An apparatus for realizing the process as claimed in any of Claim 1 to 7 comprising boundary wall/s/ around the longitudinal axis and at least one separation wall, characterised in that comprising boundary wall/s/ including at last partly acute or obtus angles with the longitudinal axis and/or with some predetermined plane /a–b/ laid across th longitudinal axis and comprising separation wall/s/, s parati n wall piece/s/ including at l ast partly alternat ly in a giv n case variable acut or btus angles with said boundary

wall/s/, comprising separation and/or boundary walls c ntracting st pwis at the input point of the media and boundary wall/s/ xpanding stepwise at the outpt point, comprising in a given case spac sections surrounded with boundary wall/s/ and of at least partly alternately expanding or contracting cross sections.

9. An apparatus as claimed in Claim 8 comprising separation wall/s/ including varying acute or obtuse angles with the longitudinal axis and/or with some predetermined plane laid across the longitudinal axis or with said boundary wall/s/ around the longitudinal axis, comprises furthermore piece/s/ of separation wall.

10. An apparatus as claimed in Claims 8 to 10 comprising discontinuities in said separation wall/s/.

11. An apparatus as claimed in any one of claims 8 to 10, comprising separation wall(s) of helical form including alternately acute or obtuse angles with the longitudinal axis, and including continuously varying angles with some predetermined plane laid across the longitudinal axis.

12. An apparatus as claimed in claim 11, comprising oppositely threaded successive separation walls.

13. An apparatus as claimed in any of claims 8 to 10 and 11 to 12, comprising separation walls turned on the tail by a given angle relative to a few or all of the separation wall ends.

14. A process for stirring materials substantially as herein described with reference to and as shown in Fig. 1 to Fig. 1c, or Figs. 2 and 2a or Fig. 3a or Fig. 3b or Figs. 4 and 4a or Figs. 5 and 5a or Figs. 6 and 6a of the accompanying drawing.

15. Apparatus for stirring materials substantially as herein described with reference to and as shown in Figs. 1 to 1c, or Figs. 2 and 2a, or Figs. 3a or 3b or Figs. 4 and 4a or Figs. 5 and 5a or Figs. 6 and 6a of the accompanying drawings.

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